# THE RETENTION OF WOODY DEBRIS STRUCTURES IN A SMALL STREAM FOLLOWING A LARGE FLOOD

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## ABSTRACT

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New Zealand streams have generally been described as having low woody debris coverage, the result of a high frequency of heavy rainfalls and of vegetation characteristics that provide streams with only small quantities of woody debris. Little is known, however, about the capacity of New Zealand streams to retain woody debris. Our investigation of different woody debris structures (log, debris, branch, twig) in a medium gradient stream before and after a large flood showed that a variable proportion of log, debris, branch and twig structures were totally disrupted or changed to a different woody debris structure, following the flood. In addition, several new log, debris and branch structures were created. Overall there were similar frequencies of pre- and post-flood log, debris and branch structures, indicating that this type of stream retains wood effectively for long periods. More investigations are needed to determine the generality of the pattern we have detected.

KEYWORDS: Stream - woody debris - floods - retention - channel morphology.

## INTRODUCTION

Woody debris exerts various and complex influences on physical, biological and chemical processes of stream ecosystems and is perhaps the most characteristic attribute of streams in forested catchments (Bryant 1983, Murphy & Koski 1989, see Harmon *et al.* 1986 and Gregory & Davis 1992 for reviews).

Most woody debris that is contributed to small streams originates from riparian vegetation (Swanson & Lienkaemper 1978, Lienkaemper & Swanson 1987, Gregory *et al.* 1991). Species composition, age and condition of riparian vegetation ultimately determine the type and volume of wood that enters the system. Types of woody debris include logs, chunks of wood (which result from degradation of logs), roots, branches and twigs. These may enter a stream as a result of biological agents, such as tree mortality caused by disease, or physical agents, such as wind throw, stream bank undercutting and debris avalanches (Keller & Swanson 1979, Murphy & Koski 1989).

Once in the stream, woody debris may be relocated by various processes, including physical fragmentation, biological breakdown and dislodgment during high discharge events (Harmon *et al.* 1986). The potential for woody debris to influence physical and biological stream processes depends to a large extent on its tendency to remain within the stream, which, in turn, is affected by factors such as size and condition of the debris and the physical characteristics of the stream, especially width (Bilby & Ward 1989).

Winterbourn *et al.* (1981) reported that it is rare for more than 5-10 % of stream beds in New Zealand forests to be covered by woody debris. They argued that this pattern was related to vegetation characteristics that provide streams with only small quantities of debris compared with elsewhere and to a high frequency of heavy rainfall events which result in elevated stream flows, producing forces capable of disrupting and transporting woody debris accumulations. If New Zealand streams have a low capacity to retain woody debris and it is important to ecosystem functioning, the effects of forest clearance and the loss of the primary source of woody debris may have particularly important implications for stream morphology, fish and invertebrate communities and the cycling of nutrients and carbon. However, little is known about the capacity of New Zealand streams to retain woody debris. In this study, we examine the pre- and post-flood composition and distribution of woody debris in a small, medium gradient, southern New Zealand stream, to determine the extent to which woody debris was lost or redistributed.

### STUDY SITE

The study was conducted in Powder Creek, a second-order tributary of Silverstream (NZMS 260-I44, J44: Map coordinates GR 867907) in the Taieri River catchment of eastern Otago in the South Island of New Zealand. Powder Creek has an average gradient of 5% (measured over 2 km of channel above the Silverstream confluence) and an active channel width of approximately 3 m. Substrate types range from fine silt and sand to medium-sized boulders overlaying a shallow bedrock base; the dominant substrate types are gravels (>5 mm < 5 cm) cobbles (> 5 cm < 10 cm) and boulders (> 10 cm). Riparian vegetation consists mostly of manuka (*Leptospermum scoparium*) with other species associated with regenerating (120 years old) lowland mixed coniferous and broadleaved forest. The coniferous species include rimu (*Dacridium cupressinum*), miro (*Podocarpus ferrugineus*), pokaka (*Elaeocarpus hookerianus*) and totara (*Podocarpus halli*). The broadleaf community is dominated by *Griselinia littoralis* but *Neopanax*, *Coprosma* and *Pittosporum* species are also common in the understory as is *Fucia exorticata*, mapou (*Suttonia australis*) and *Nothopanax* species. Watt & Leslie (1968) noted that stream beds of the upper forested Silverstream catchment were relatively stable, with well vegetated banks and little erosion. This still appears to be the case.

The area is subject to a cool temperate climate with annual rainfall in the range of 1120-1200 mm, evenly spread through the year. Powder Creek has a quick flow response to rainfall events followed by slow recession (Watt & Leslie 1968). Watt & Leslie (1968) noted that a total of twenty seven floods (approx. bankfull flow) occurred over a 33 year period (1920-1953), showing little seasonal pattern except that the five most severe floods all occurred during autumn.

## MATERIALS AND METHOD

An 800 m stretch of Powder Creek, starting at its confluence with Silverstream, was mapped in April 1990 in relation to three channel categories defined according to the appearance of the water surface: pool - slow, deeper water with a smooth surface; run - faster water, usually deeper than a riffle, and showing a smooth or undular rather than broken surface; riffle - fast water showing a considerable amount of broken water surface.

The length of each pool, riffle and run was measured and the distribution of woody debris within each was noted. For the purpose of this study, woody debris was identified as any woody matter with a mean stem diameter greater than 5 mm, grouped into one of four categories according to the size and composition of wood present:

(1) Log: A single piece of woody debris greater than 10 cm stem diameter, occurring totally or partially within the bankfull stream channel at any angle to the main flow. This category includes such items as fallen trees, logs and chunks of wood.

(2) Debris accumulation: A collection of various sized pieces of wood, usually consisting of a log that has become lodged within the stream and has accumulated other woody debris. The accumulation may extend across any width of the stream.

(3) Branch: One or more tree branches that extend into the stream; such structures typically consist of branches of a tree that has fallen near the stream bank. Branches may extend partially over the stream or across its whole width. If branches are attached to a trunk > 10 cm diameter and are in the water, it is recorded as a log. If branches have accumulated at least 5 sticks (> 1 cm diameter), the structure is recorded as a debris accumulation.

(4) Twig accumulation: A collection of small twigs, many of which have accumulated leaf and other small particulate organic matter. These generally do not extend across more than two thirds of the width of the stream.

Powder Creek was mapped again in September 1990, following a one-in-30 year flood on 24 September. During the flood, the peak flow in the lower Silverstream was 85 $m^3 s^{-1}$ whereas flow readings for this time of year are usually approximately 0.8 $m^3 s^{-1}$ (Otago Regional Council, Environmental Data Division). No other major discharge events (stream flows rising to at least one half of the bankfull height above the original water levels at first mapping) occurred between the first and second mapping dates.

By using the original mapping sheet we were able to relocate the original wood structures and identify any new ones. Where a wood structure remained unchanged from the original survey it was re-recorded as such. Structures that had changed to a new type by either losing or accumulating woody debris were recorded as the new type. The occurrence of any new wood structures was also noted.

For the purposes of statistical analysis, the 800 m stretch of stream was divided into eight 100 m segments. These could be taken as largely, if not completely, independent of each other in terms of the wood structures they contained. A two-way ANOVA was performed on the frequencies of the wood structures (log, debris, branch, twig) in the eight segments before and after the flood.

## RESULTS

Prior to the flood a total of 35 woody debris structures were recorded in the mapped section of stream. Twig accumulations comprised thirteen of these, log structures were the next most common with nine structures followed by eight debris and five branch structures.

Prior to the flood, five of the nine log structures were associated with pools, whereas two each occurred in runs and riffles (Fig. 1). Two debris structures each occurred in runs and riffles and four in pools. Only one of the five branch structures recorded occurred in a pool, whilst two each were located in riffles and runs. The thirteen twig accumulations were mostly associated with riffles; only two twig structures occurred in runs and one in a pool.

Powder Creek was visibly affected by the flood; depth had increased during the flood in places by up to 1 m, and the substrate had lost all visible signs of algae.

Following the flood, all twig accumulations had been removed from the mapped section of stream (Table 1). Six new wood structures were recorded after the flood (3 debris and 3 branch) (Table 1). Of the pre-flood log structures, 56% remained intact as well as 38% of the debris and 20% of the branch structures (Table 2). Of the debris structures, 38% were completely disrupted following the flood whereas 24% were partially disrupted, leaving only the large retaining log, and were reclassified accordingly . On the other hand, 11% of the pre-flood log structures and 60% of the pre-flood branch structures had accumulated wood and were reclassified as debris structures (Table 2). A significant difference occurred in the frequency of wood structures per 100 m of stream before and after the flood ($F = 4.245$, $p = 0.044$), mainly because of the decline in twig structures. No significant difference was detected between the frequencies of the different categories of structures ($F= 0.275$, $p = 0.27$), but a significant interaction effect was found ($F =4.597$, $p = 0.006$) reflecting the unordered changes in frequencies of the four categories before and after the flood (Fig. 2).

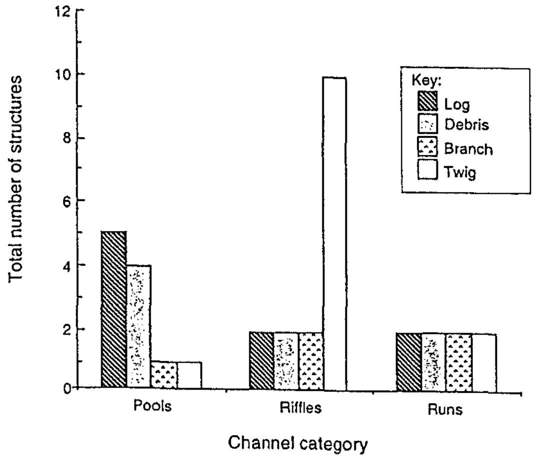


Figure1. Numbers of the four woody debris structures in pools, riffles and runs in the 800 m stretch of Powder Creek 5 months prior to the flood.

## DISCUSSION

Streams surrounded by forests generally receive substantial inputs of woody debris every few decades or centuries as a result of climatic or ecological perturbations (Harmon *et al.* 1986). The wood is then gradually fragmented through various pro-

Table 1. Total number of four categories of woody debris structures recorded before and after the flood and the number that remained intact, the number that were reclassified into the category and the number that were new.

| Woody debris structure | Number before flood | Number after flood | Number that remained intact | Number reclassified from another category | Number that were new |
|---|---|---|---|---|---|
| Log | 9 | 7 | 5 | 2 | 0 |
| Debris | 8 | 10 | 3 | 4 | 3 |
| Branch | 5 | 4 | 1 | 0 | 3 |
| Twig | 13 | 0 | 0 | 0 | 0 |

Table 2. Transition probabilities (expressed as percentages) between woody debris structures (WDS) as a result of the flood.

| Pre-flood WDS | Post-flood WDS | | | | |
|---|---|---|---|---|---|
| | Log | Debris | Branch | Twig | Lost |
| Log | 56 | 11 | 0 | 0 | 33 |
| Debris | 24 | 38 | 0 | 0 | 38 |
| Branch | 0 | 60 | 20 | 0 | 20 |
| Twig | 0 | 0 | 0 | 0 | 100 |

cesses of flood events and physical and biological breakdown. The capacity of a stream to retain wood through subsequent high discharge events can have important implications for the structure and functioning of the ecosystem. All wood structures identified in Powder Creek during the first mapping had accumulated large amounts of leaf material, particularly noticeable in the case of twig structures. By storing leaves and other organic matter, wood dams increase the time for processing and utilisation of the matter within the stream (Keller & Swanson 1979, Bilby 1981, Beschta & Platts 1986).

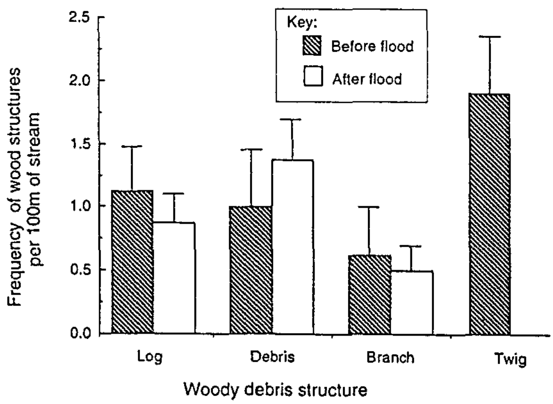


Figure 2. The mean frequency (per 100 m segment of stream channel) (+1SE) of the four woody debris structures 5 months before and immediately after the flood.

The morphology of a stream can play an important role in determining the formation and distribution of woody debris structures. Thus, twig accumulations occurred most often in riffles where the twigs became lodged between stones and subsequently accumulated leaf and other small particulate organic matter. Branch structures also occurred in riffles, but their distribution was more a function of where trees happened to fall rather than of stream structure. Log structures tended to cause small waterfalls and plunge pools; in some cases, therefore, the wood structures were the cause of the observed pattern and the channel form the consequence.

Only one major flood occurred during the 5 months between mapping dates so we have assumed that the substantial branch, debris and log structures were present immediately prior to the flood. As twig structures are very unstable, a number could have been removed and reformed before the flood during minor rises in stream level. The role of wood size in relation to the active channel width may also be an important factor influencing the stability and retention of woody debris in streams. Larger log structures proved to be most effective at withstanding the high discharge, followed by debris and branch structures, with twig accumulations the least stable.

Although this one-in-30 year flood affected the distribution of woody debris, it does not appear to have greatly affected the amount of substantial pieces of wood, other than twigs, within Powder Creek. It is possible that other medium gradient streams, similar in nature to Powder Creek, will also retain wood effectively for long periods. However, our data relate to only one small forested stream and a larger survey of woody debris in different streams before and after floods is needed to determine the generality of the pattern we have detected.

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